Rocky Mountains Southwest Great Plains

Research Note RM-464

March 1986

USDA Forest Service

Rocky Mountain Forest and Range Experiment Station

Effect of a Prescribed Burn in Ponderosa Pine on Inorganic Nitrogen Concentrations of Mineral Soil

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Soil inorganic nitrogen was measured during the summer after a fall prescribed burn at a ponderosa pine site in northern Arizona. Fire behavior varied among sawtimber, pole, and sapling stands; the greatest fuel reduction occurred in the sawtimber. Ammonium-nitrogen content of the upper 15 cm of soil in the burned sawtimber plots was as much as 80 times greater than in unburned plots. This is approximately 70 kg ha^{-1} more available N, a major fertilizing effect. The soil under the burned pole plots had a slightly greater inorganic nitrogen content than under unburned plots, while burning did not change the soil inorganic nitrogen in the sapling plots. The increased availability of nitrogen after burning may affect regeneration, understory growth, and growth of overstory trees.

Keywords: Fire ecology, inorganic nitrogen, nitrification, forest soils, prescribed burning.

Fire has been excluded from many ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) stands in the Southwest for 60 to 100 years because of herbaceous fuel reduction associated with heavy grazing, and wildfire suppression activities. Exclusion of fire has changed the structure of the timber stands (Cooper 1960) and has caused heavy accumulations of forest floor and woody fuels (Biswell 1972). Consequently, the average size and severity of wildfires in this type have increased greatly.[3]

Since the late 1940s, land managers in the Southwest have been using prescribed burning to reduce heavy fuel loads. Prescribed burning in ponderosa pine can have a variety of immediate effects including plant mortality, fuel reduction (Sackett 1980), and partial surface sterilization (Landsberg and Cochran 1980). Over longer periods, burning may alter soil temperature, moisture, and nutrient relations (Fuller et al. 1955, Vlamis et al. 1955), and thereby affect growth of woody and herbaceous plants. Because nitrogen availability frequently is limiting in ponderosa pine ecosystems (Wagle and Beasley 1968, Wagle and Kitchen 1972, Heidmann 1985), changes in nitrogen mineralization after burning are especially important. This note reports the results of a study of soil inorganic nitrogen content during the summer after a fall prescribed burn. These first-year effects are important for understanding changes in seedling establishment and growth, understory production, forage quality, and nutrient losses resulting from burning.

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[3] *Barrows, Jack S. 1978. Lightning fires in southwestern forests. Final report prepared by Colorado State University for Intermountain Forest and Range Experiment Station, under Cooperative Agreement 16-568-CA with Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo., 154 p.*

Research Area

The Chimney Spring area is in the eastern part of the Fort Valley Experimental Forest, about 10 km northwest of Flagstaff, Ariz. The Fort Valley Experimental Forest was established in 1908 and is considered to be representative of ponderosa pine in the Southwest. The climate is subhumid to humid, combined with cool temperatures; the ponderosa pine type is also characterized by deficient early summer moisture. Mean annual temperature at Fort Valley is 7°C, and the mean annual precipitation is 57.4 cm (Schubert 1974). Approximately one-half of the precipitation falls as snow.

The soil is a Brolliar stony clay loam, tentatively classified as a fine, montmorillonitic, frigid, typic Argiboroll.[4] Brolliar soils have a low infiltration rate, and depth to basalt flow rock is typically 50–100 cm.

The ponderosa pine stand studied was characterized by groups of even-aged trees clustered within an uneven-aged stand. The average number of stems per hectare for each overstory size class was: saplings (1.5–9.9 cm d.b.h.)—2,750, poles (10.0–27.5 cm d.b.h.)—770, and sawtimber (greater than 27.5 cm d.b.h.)—130 (Sackett 1980). Basal area averaged 33 m^2 ha^{-1} for all trees 10 cm d.b.h. or larger, (Sackett 1980). No fire had occurred for 100 years prior to the 1976 prescribed burn (Dieterich 1980); before 1876, fires burned at approximately 2-year intervals. The area was virtually undisturbed by harvesting (Sackett 1980). The elevation ranges from 2,195 m to 2,255 m with gentle slopes (0–5%).

The study area was burned at night using a combination of backing fires and short strip head fires. A description of conditions before and after the burn and of the burn itself was presented by Sackett (1980). Tree mortality from burning was confined to isolated mature trees and to younger trees near heavy fuel accumulations. Overall, forest floor material less than 2.5 cm diameter was reduced by 63% from 32.0 to 11.9 metric tons ha^{-1}. The greatest reduction in forest floor depth occurred in the sawtimber type, perhaps because of high pre-burn fuel loading (Sackett 1980). The amount of litter consumed on the pole plots varied from light to heavy, while litter consumption on the sapling plots was slight (Sackett 1980). Changes in nutrient content of the woody debris and forest floor were reported in Covington and Sackett (1984).

Methods

Twenty-eight 1 ha plots, with five permanent basal area points each, were established (Sackett 1980); 18 plots were burned in November 1976. North-south and east-west lines that intersected the basal area points defined a set of quadrants. Each quadrant was classified into one of three categories—saplings, poles, or sawtimber—based on the composition of the overstory in that quadrant. Quadrants with large downed logs, roads, stumps, or mixed overstory were excluded from the study (20% of the quadrants). The dominant overstory type was pole (55% of the quadrants), followed by sawtimber (15%) and sapling (10%).

Information from preliminary sampling was utilized to determine the most time-efficient combination of the number of composite samples per overstory cover class and subsamples per composite that would yield a variance low enough to detect meaningful changes in soil inorganic nitrogen content (Falck 1973). The combination of 4 randomly selected quadrants per treatment and 10 subsamples per quadrant was used.

In each quadrant, three 7 m sampling lines were established at angles of 23°, 45°, and 67° from the quadrant boundaries. Mineral soil was sampled at randomly selected 10 cm intervals along these sample lines; the 0 to 2 m interval of each sample line was excluded to avoid sampling the effects of trampling around the plot center. All litter, including partially burned fragments, was removed before soil core samples were taken. For each collection period, soil cores were extracted and composited from each of 10 randomly selected segments in each quadrant.

The mineral soil was sampled with a soil corer to a depth of 15 cm. Samples were stored under ice in a cooler prior to analysis. Soils were sampled four times in 1977, beginning 8 months after the fire—July 14, July 29, August 5, and August 25 (periods 1–4, respectively).

Field moist soils were used for laboratory analysis. The composite samples were screened and the fractions greater than 2 mm were discarded. A 25 g subsample was placed in a preweighed container, weighed, dried to a constant weight at 105° C, and reweighed to determine moisture content. A 1:1 soil to water paste was used to determine pH on a separate sample.

A representative sample (20–25 g) of the wet soil (<2 mm) was weighed and placed in a 500 ml flask; 2N KC l (10 ml per gram of wet soil) was added in order to extract the inorganic nitrogen (Bremner 1965). The soil and extractant solution was shaken intermittently for 1 hour, was filtered, and the filtrate then was refrigerated. All samples were extracted the same day they were collected, and were analyzed within 3 weeks.

Ammonium-nitrogen (NH_4^+-N) and nitrite (NO_2^--N) plus nitrate-nitrogen (NO_3^--N) was determined by macrodistillation with MgO and Devarda's alloy—an adaptation of the steam distillation method (Bremner 1965). Because the predominant form of oxidized nitrogen in these soils is nitrate, nitrite plus nitrate-nitrogen is designated as NO_3^--N in this note. Caution should be exercised in comparing these distillation results with those obtained by the colorimetric AutoAnalyzer procedure. For example, White and Gosz (1981) found that standard automated techniques may overestimate NH_4^+-N in some samples, perhaps because of amino acid interference.

The experiment was a two-factor analysis of variance with repeated measures: two treatments (burn and control), three overstory size classes (sapling, pole, and sawtimber), and four sampling dates (periods 1–4),

[4]*Based on an adjacent area in Meurisse, R. T. Unpublished. Soils report San Francisco Peaks Area—Elden and Flagstaff Ranger Districts, Coconino National Forest. USDA Forest Service, Division of Watershed Management, State and Private Forestry, Southwestern Region, Albuquerque, New Mexico.*

repeated within treatment and size class. Differences between cell means were tested using Scheffe's test. Significance level of all tests was 0.05.

Results

Overall, soil from burned plots had significantly more NH_4^+-N than soil from unburned plots (table 1). Consistent differences were present only in the sawtimber class. The NO_3^--N content of burned soils for all overstory classes combined was not significantly greater than that of unburned soils (table 2). However, the sawtimber burn means for NO_3^--N were significantly different from all other treatment and overstory combinations for sample periods 3 and 4 (table 2).

There were significant differences among size classes for NH_4^+-N means, but not for NO_3^--N means. Treatment-overstory interactions were significant in both cases. The treatment-overstory interaction shows that the treatment effect was present only in the sawtimber burn class for NH_4^+-N; the interaction may have masked the effect of the treatment for NO_3^--N. Pole burn plots had higher NH_4^+-N than the pole control plots, but the differences were not significant (table 1).

Differences across overstory classes and between periods were significant for NO_3^--N, but not for NH_4^+-N (tables 1 and 2). For nitrate, periods 1 and 2 were significantly greater than periods 3 and 4 for all treatment-overstory combinations, except for the sawtimber burn. Levels of both NH_4^+-N and NO_3^--N appeared to decline throughout the summer for all control plots. The soil NO_3^--N also declined for the burned pole and sapling plots.

There was no signifcant difference between treatments for soil moisture content; however, the difference between periods was significant. Overall, periods 1 and 2 had a higher soil moisture content than periods 3 and 4. The moisture content of the sawtimber burn plots remained constant for all four periods and was significant-

Table 1—Mean (Standard Error) NH_4^+-N Content of 0-15 cm Mineral Soil (μg/g soil)[1].

		Period 1	2	3	4
SAWTIMBER	Burn	45.05 (10.10)$^{(a,x)}$	44.27 (5.54)$^{(a,x)}$	45.42 (6.42)$^{(a,x)}$	41.38 (9.67)$^{(a,x)}$
	Control	2.25 (0.24)$^{(b,x)}$	3.01 (0.16)$^{(b,x)}$	0.98 (0.24)$^{(b,y)}$	0.52 (0.22) $^{(b,y)}$
POLE	Burn	4.18 (0.85)$^{(b,x)}$	7.31 (2.31)$^{(b,y)}$	5.81 (1.98)$^{(b,x)}$	1.36 (0.65)$^{(b,x)}$
	Control	2.05 (0.50)$^{(b,x)}$	1.66 (0.22)$^{(b,xy)}$	0.72 (0.09)$^{(b,xy)}$	0.48 (0.16)$^{(b,y)}$
SAPLING	Burn	1.30 (0.24)$^{(b,x)}$	2.26 (0.32)$^{(b,x)}$	1.17 (0.25)$^{(b,x)}$	0.38 (0.23)$^{(b,x)}$
	Control	2.63 (0.18)$^{(b,x)}$	2.31 (0.40)$^{(b,x)}$	0.83 (0.32)$^{(b,y)}$	0.61 (0.17)$^{(b,y)}$

[1]*Because the interaction between treatment and overstory was significant, treatment means were either compared within a period (a,b) or within an overstory-treatment combination across periods (x,y). Means with the same letter are not significantly different using Scheffe's test.*

Table 2—Mean (Standard Error) (NO_2^- + NO_3^-)-N Content of 0-15 cm Mineral Soil (μg/g soil)[1].

		Period 1	2	3	4
SAWTIMBER	Burn	3.95 (0.92)$^{(a,x)}$	3.47 (0.46)$^{(a,x)}$	3.15 (0.77)$^{(b,x)}$	4.16 (1.43)$^{(b,x)}$
	Control	2.89 (0.21)$^{(a,x)}$	3.36 (0.20)$^{(a,x)}$	1.06 (0.16)$^{(a,y)}$	0.49 (0.20)$^{(a,y)}$
POLE	Burn	3.32 (0.37)$^{(a,x)}$	3.37 (0.26)$^{(a,x)}$	1.32 (0.12)$^{(a,y)}$	0.88 (0.07)$^{(a,y)}$
	Control	3.31 (0.34)$^{(a,x)}$	3.43 (0.09)$^{(a,x)}$	1.32 (0.08)$^{(a,y)}$	0.62 (0.15)$^{(a,y)}$
SAPLING	Burn	2.98 (0.15)$^{(a,x)}$	2.86 (0.25)$^{(a,x)}$	1.23 (0.11)$^{(a,y)}$	0.21 (0.15)$^{(a,z)}$
	Control	3.34 (0.18)$^{(a,x)}$	3.24 (0.11)$^{(a,x)}$	1.22 (0.09)$^{(a,y)}$	0.38 (0.10)$^{(a,z)}$

[1]*Because the interaction between treatment and overstory was significant, treatment means were either compared within a period (a,b) or within an overstory-treatment combination across periods (x,y). Means with the same letter are not significantly different using Scheffe's test.*

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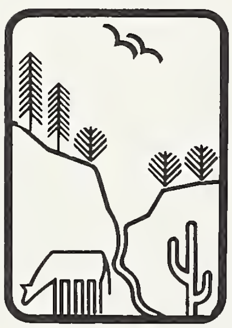

Southwest

Great Plains

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